IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

#5

In re Application of

GERARD DE HAAN ET AL.

Atty. Docket

NL010094

jc821 U.S. PTO
09/855628
05/15/01

Filed: CONCURRENTLY

MOTION ESTIMATOR FOR REDUCED HALOS IN MC UP-CONVERSION

Commissioner for Patents, Washington, D.C. 20231

AUTHORIZATION PURSUANT TO 37 CFR §1.136(a)(3)
AND TO CHARGE DEPOSIT ACCOUNT

Sir:

The Commissioner is hereby requested and authorized to treat any concurrent or future reply in this application requiring a petition for extension of time for its timely submission, as incorporating a petition for extension of time for the appropriate length of time.

Please charge any additional fees which may now or in the future be required in this application, including extension of time fees, but excluding the issue fee unless explicitly requested to do so, and credit any overpayment, to Deposit Account No. 14-1270.

Respectfully submitted,

By

Edward W. Goodman, Reg. 28,613
Attorney
(914) 333-9611

F:\WPDOCS\GO\NL010094.APPR.doc

PHNL 000295 W.

NL 010094

Europäisches Patentamt **European Patent Office** **Office européen des brevets**

I

JC821 U.S. PTO
09/855628
05/15/01

Bescheinigung Certificate Attestation

Die angehefteten Unterlagen stimmen mit der ursprünglich eingereichten Fassung der auf dem nächsten Blatt bezeichneten europäischen Patentanmeldung überein.

The attached documents are exact copies of the European patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

Patentanmeldung Nr. Patent application No. Demande de brevet n°

00201752.3

CERTIFIED COPY OF PRIORITY DOCUMENT

Der Präsident des Europäischen Patentamts; Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets p.o.

I.L.C. HATTEN-HECKMAN

BEST AVAILABLE COPY

DEN HAAG, DEN

Blatt 2 der Bescheinigung
Sheet 2 of the certificate
Page 2 de l'attestation

Anmeldung Nr.:
Application no.: 00201752.3
Demande n°:

Anmeldetag:
Date of filing: 18/05/00
Date de dépôt:

Anmelder:
Applicant(s):
Demandeur(s):
Koninklijke Philips Electronics N.V.
5621 BA Eindhoven
NETHERLANDS

Bezeichnung der Erfindung:
Title of the invention:
Titre de l'invention:
NO TITLE

In Anspruch genommene Prioriät(en) / Priority(ies) claimed / Priorité(s) revendiquée(s)

Staat: State: Pays:	Tag: Date: Date:	Aktenzeichen: File no. Numéro de dépôt:

Internationale Patentklassifikation:
International Patent classification:
Classification internationale des brevets:
/

Am Anmeldetag benannte Vertragstaaten:
Contracting states designated at date of filing: AT/BE/CH/CY/DE/DK/ES/FI/FR/GB/GR/IE/IT/LI/LU/MC/NL/PT/SE/TR
Etats contractants désignés lors du depôt:

Bemerkungen:
Remarks:
Remarques:

No title

We present a new block-based motion estimation strategy, which is able to correctly find the velocity of background blocks in occlusion areas (covering or uncovering). For covering, we perform the matching for blocks in the future picture, of the picture pair used for the motion estimation, fetching the corresponding blocks from the past picture. In uncovering areas of the picture we match the blocks in the past picture with the blocks fetched from the future image. For the *rigid* motion of blocks in non occlusion areas, we fetch the blocks bidirectionally from both the past and future picture, projecting to the interpolated picture halfway between the past and future pictures. We then retime the obtained vector field so that it corresponds to the desired time moment, of the interpolated picture . The result of these two operations is a vector field that fits the image objects very well, whereas non "occlusion robust" methods can not estimate the background vectors correctly in the occlusion areas, which typically leads to foreground vector field regions that are larger than the corresponding image objects. In upconversion this leads to an annoying *halo* around the foreground objects, which can manifest itself as a noisy flicker, blur or parts of the background attached to the foreground objects. Occlusion is a problem that plagues all block based motion estimation methods, and hence we see a utility of the method for applications like video compression, 3D matching or image sequence object extraction.

1 Introduction

For real-time motion estimation we have developed the 3D recursive search block matcher [1], which in contrast to the full search block matcher [2] does not have to evaluate all possible motion vectors within certain limits, but only a number of smartly chosen candidates. We determine which of these candidates describes the motion of the block under study the best, and this usually yields a high quality vector field. The criterion which determines which motion vector among the presented candidates is the best one, is the minimisation of the sum of absolute differences or SAD (eq. 1):

$$\epsilon(\vec{C},\vec{X},n) = \sum_{\vec{x}\in B(\vec{X})} \left|F(\vec{x}-\alpha\vec{C},n-1) - F(\vec{x}+(1-\alpha)\vec{C},n)\right| \quad (1)$$

In this equation $B(\vec{X})$ is the block of selected pixels at position $\vec{X}$ ($\delta x = 0\ldots8$ by $\delta y = 0\ldots8$), $\vec{C}$ the candidate vector under scrutiny, n the picture number or moment in time and α a constant, $0 \leq \alpha \leq 1$, determining the temporal position between the two pictures, to which the fetched blocks are projected for the match. In [1] we performed this match on the temporal position where the vector field was desired, hence the position halfway in between the two selected pictures, ($\alpha = 0.5$), which resulted in impossible matches in the occlusion regions, because in one of the pictures the background blocks are covered.

2 Description of the new motion estimator strategy

2.1 The tritemporal motion estimator

We realised that in the case of e.g. covering, all pixel blocks that are present in and around the occlusion area in the future picture can also be found in the past picture. However in the past picture there are extra blocks, which no longer exist in the future picture, because they become covered. A natural position to put the reference position α for block matching is at the temporal position of the future picture (α=1), since then for all blocks in and around the occlusion area a correct motion vector can in principle be found.

Fig. 1a shows more clearly what happens for all possible reference positions $0 \leq \alpha \leq 1$. Suppose that the upper line a corresponds to the position of the edge of the foreground object travelling through time. Then in the future picture we find the correct foreground or background velocities on either side of the velocity vector edge position X_E (position where the motion vector displays a significant spatial change). But the more we move the reference position α towards the past picture, the larger the ambiguity region becomes, in which it is impossible to find the correct vector by matching. Since all candidate vectors will have a large SAD value, minimisation *randomly* selects a certain candidate, which means that the resulting vector fields are almost impossible to correct.
Similarly from fig. 1b we learn that for uncovering regions an unambiguous motion estimation results if we put the reference position α equal to 0, in other words we project blocks from the future to the past. For rigid motion no errors occur if we put the reference position in the middle ($\alpha = 0.5$). The decision whether an area is a covering or uncovering area is done based upon the sign of the difference of the motion vectors' x-components taken from either side of the vector edge X_E in the previously calculated vector field, according to the *occlusion detector* we described in [3].

The vector field obtained by locally changing the reference position α for block matching according to the output of the occlusion detector, is a motion vector field that is not valid for any temporal position between the past and current pictures, since it is in fact obtained by "gluing together" sub vector fields which are valid at different temporal positions (*tritemporal*). Therefore the vector field has to be *retimed* to the desired upconversion position (typically $\alpha = 0.5$).

2.2 The retimer

In the motion vector field originating from the tritemporal estimator, all vectors in the interpolated picture between X_E and the true edge position of the foreground (the point on line a at the time $n + \alpha$) are incorrect. In the covering example we described with the aid of fig. 1a, that they will be foreground vectors but should be background vectors. The retimer performs two actions. First it determines the true edge position of the foreground by calculating the intersection of the line projecting X_E with the foreground velocity, and the interpolated picture plane. Secondly it determines whether the foreground or background should be assigned to the blocks in the incorrect region, depending on:

1. whether we have covering or uncovering
2. the sign of the foreground velocity
3. on which side the foreground is

It is obvious that for both actions we need to know which velocity is the foreground velocity and which one the background velocity. For this we developed 3 foreground/background determination strategies. The one we prefer to use projects X_E with both velocities (on either side of X_E) to the previous vector field (at time n for the covering example), and determines around both positions whether there is a vector edge. The velocity that projects to the edge is the foreground velocity.
As a practical illustration fig. 2 shows how well the retimed vector field fits to the image object. Notice that the part of the background that is selected (by using the motion vector image as a selection mask) in the new method is much smaller, especially behind the head, which in our video rate conversion application results in a drastically reduced halo around the head.

References

[1] G. de Haan, P.W.A.C. Biezen, H. Huijgen and O.A. Ojo, "True Motion Estimation with 3-D Recursive Search Block-Matching", IEEE Tr. on Circuits and Systems for Video Technology, Vol.3, October 1993, pp. 368-388.

[2] A.M. Tekalp, "Digital Video Processing", Prentice Hall PTR, 1995, ISBN 0-13-190075-7.

[3] G. de Haan and A. Pelagotti, 'Problem area location in an image signal', Philips patent application no. PHN17.065, 20-08-98.

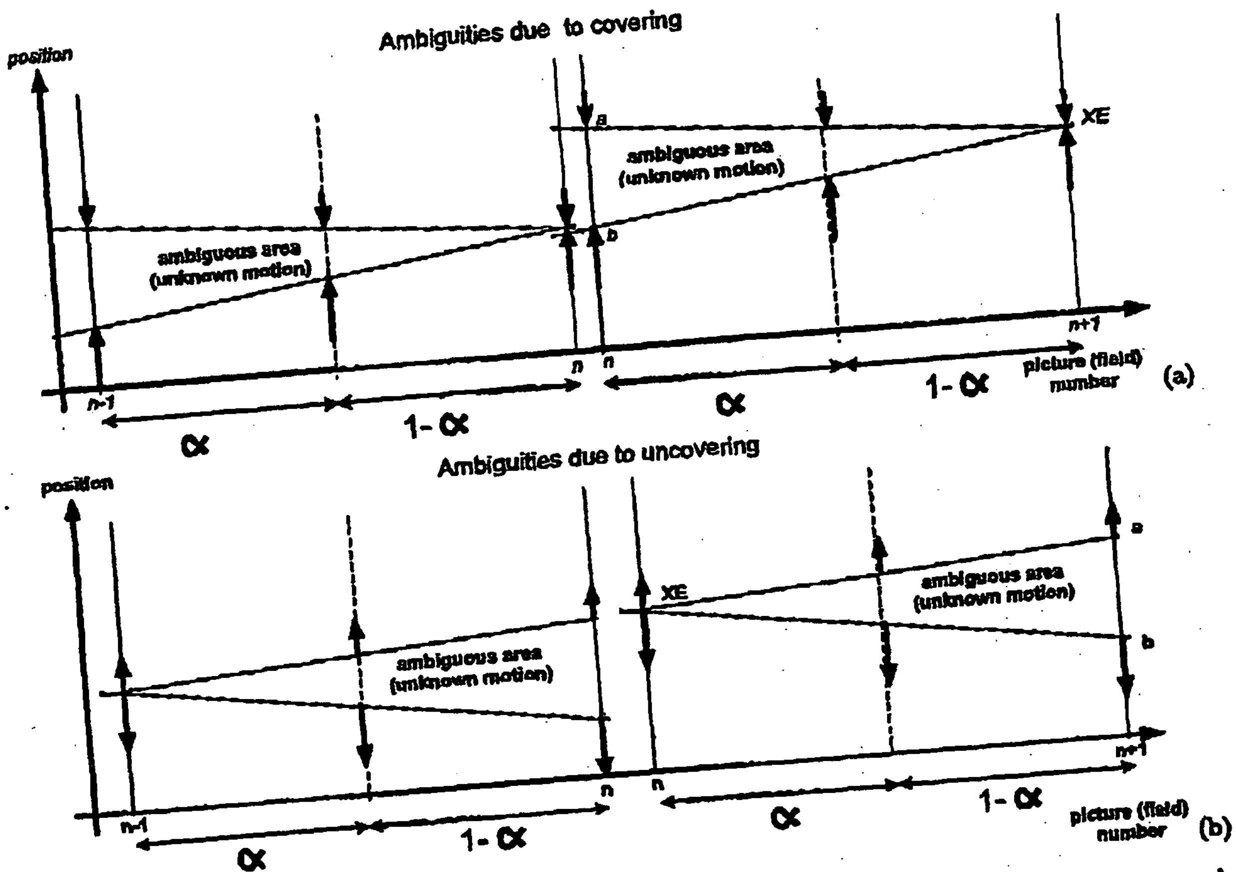
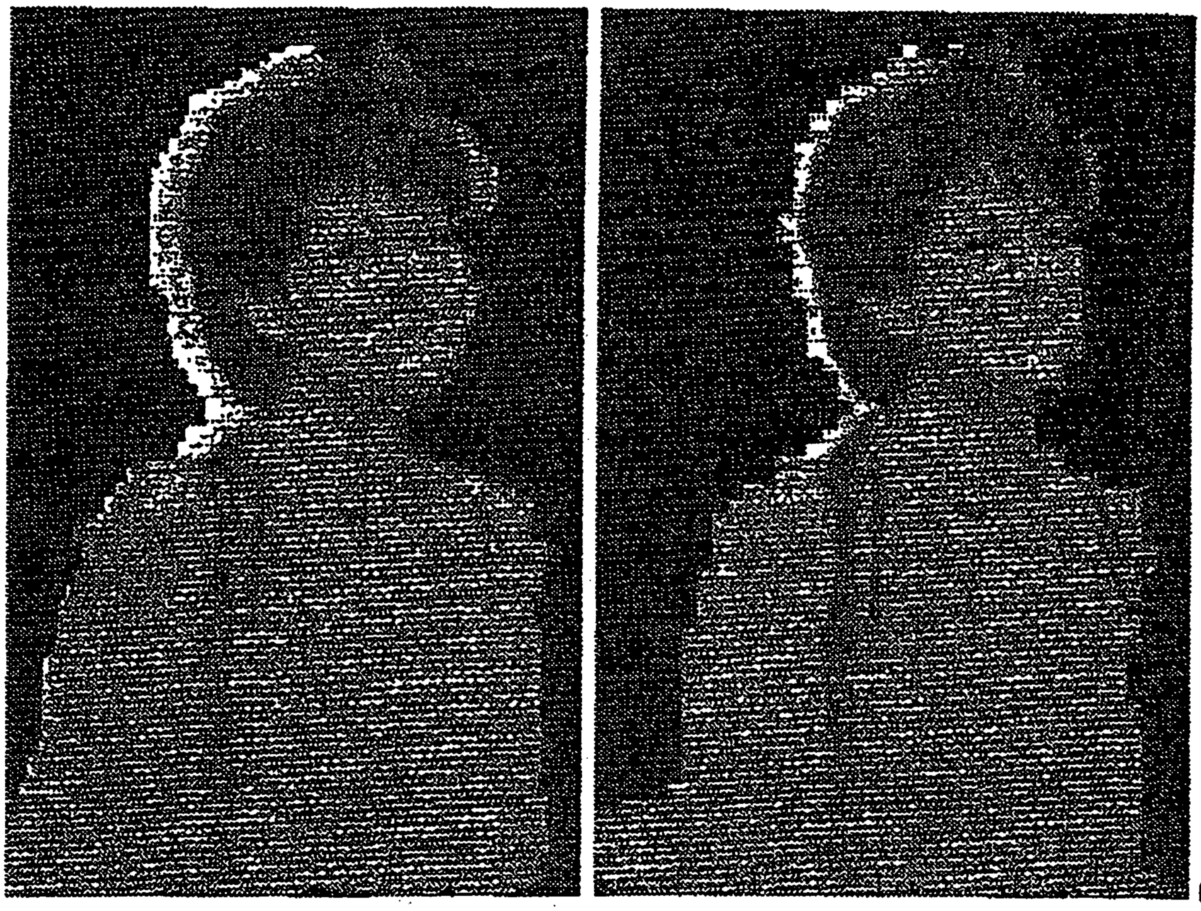


Figure 1: In case of covering, (a), unambiguous motion estimation can result only from calculating the match errors by projecting a previous picture block towards the current, as the previous picture contains all information present in the current. In case of uncovering, (b), unambiguous motion estimation can result only from calculating the match errors by projecting a current picture towards the previous.



(a)

Figure 2: Left: The Renata object extracted from the image with the calculated vector field for classical non occlusion robust processing ($\alpha = 0.5$ always). Right: Renata extracted with the vector field obtained from the new motion estimator.

The invention can be applied in various areas. Examples are given below.

In picture rate conversion, where an improved vector field according to the invention results in a more pleasing, artefact free video stream. Typical devices for this application are TV and PC.

In 3D disparity analysis, where images are generated by a rolling camera or from a rolling scene.

In motion based video compression, where an improved vector field according to the invention results in higher quality predictions and therefore in higher compression ratios or improved picture quality. An example is compression in MPEG.

In motion based image analysis, where an improved vector field according to the invention results in a more faithful extraction of objects and hence in easier post-processing. Examples are: security camera video analysis, video special effects, and traffic analysis.

Picture enhancement in television techniques, e.g. avoidance of blurring of background.

In scientific application, where an improved vector field according to the invention results in a better data analysis. Examples are satellite photos of clouds and oceanography.

A new block matching motion estimator is proposed, enabling a superior performance for applications in picture rate conversion. Particularly, the invention describes a modification to the match error calculation, which enables the estimation of a more precise motion vector in areas of covering and uncovering, leading to reduced halo artifacts in interpolated images. The essence of the invention consists of shifting the match error calculation from the current picture pair to the previous picture pair or to the next picture pair, for image parts that are being covered, or uncovered, respectively.

Keywords: **motion estimation, block matching, video format conversion, halo reduction.**

1 Prior art

In [1] a method was disclosed for motion compensated picture interpolation that reduces the negative effect of covering and uncovering, near discontinuities in the velocity field, on the quality of interpolated images. In the described case, which applies an order statistical filter in the upconversion to replace the common MC-averaging, interpolated pictures result from pixels taken from both adjacent pictures. The current invention is an elaboration of this original idea, and basically modifies the interpolation strategy depending on a segmentation of the image in various areas.

In [2] a segmentation for the same purpose was described. This segmentation is based on a motion detector, and can only realize reliable results if covering and uncovering occur of *stationary* backgrounds. The current invention claims to be valid even if both foreground and background are moving.

In [3] a method was disclosed that allows a reduction of halo defects in architectures that enable access to one field only, or in systems particularly designed to have access to one field only in order to obtain the increased resolution of an interpolation according to [4].

In [5] a method was disclosed that allows a reduction of halo defects in architectures that enable access to two fields, where the method relies on the use of two motion vector estimators, a so called *forward* and a *backward* estimator.

In [6] a method was disclosed that allows identification of areas in which covering or uncovering takes place, analysing the vector field around discontinuities.

In the current invention disclosure, we shall use the method described in [6] to locally modify the match error calculation of a block matching motion estimator, in order to arrive at a more precise vector field that allows us to interpolate images at temporal positions in between input fields, where the interpolated images exhibit a reduced halo artifact compared to image resulting from a non-modified block matcher.

2 Method according to the present invention

The basic observation from which the current invention results is that an estimator estimating motion between two successive pictures from a video sequence, cannot perform well in areas where covering or uncovering occurs, as it is typical for these areas that the information only occurs in either of the two images. Block matchers, as a consequence will always find large match errors even for the correct vector. It is recognized, however, that in the case of covering all information in the current picture *is* present in the *previous* picture pair, while in the event of uncovering the *next* picture(s), while in an area of uncovering, the current picture contains all infromation of the previous one (locally around the uncovering area). Ergo, by

modifying the match error calculation, controlled by a covering/uncovering detector, e.g. the one disclosed in [6], from matching the current picture with the motion compensated previous picture (covering) to matching the previous picture with the motion compensated current picture (uncovering), any ambiguity in the estimator can be prevented. This is expected to yield more accurate and consistent vector fields and therefor reduced halo. This modification shall be elaborated in subsection 2.2.

As a side effect of this dynamically changing match calculation, the resulting unmabiguous vector field is no longer valid for one moment in time, let alone the moment where the upconversion takes place, but this 'validity moment' changes depending on the area under consideration being a covering, uncovering or simple rigidly moving area. This side effect can be eliminated with a second ingredient of this disclosure, described in subsection 2.3.

In the next subsection, we shall elucidate the improved motion vector calculation using the full-search block-matching motion estimator to calculate the motion vectors. This algorithm is not a very cost-effective approach to the motion estimation problem, but the more effective ones, e.g. [7, 8] are based on the same principle.

2.1 The full search block matcher

In block-matching motion estimation algorithms, a displacement vector is assigned to the centre $\vec{X} = \begin{pmatrix} X_x \\ X_y \end{pmatrix}$ of a block of pixels $B(\vec{X})$ in the current picture n by searching for a similar block within a search area $SA(\vec{X})$, also centred at $\vec{X}$, but in the previous picture $n-1$. The similar block has a centre, which is shifted with respect to $\vec{X}$ over the displacement vector $\vec{D}(\vec{X}, n)$.To find $\vec{D}(\vec{X}, n)$, a number of candidate vectors $\vec{C}$ are evaluated by applying an error measure $(\vec{C}, \vec{X}, n)$ to quantify block similarity. Figure 1 illustrates the procedure. More formally, CS^{max} is defined as the set of candidates $\vec{C}$, describing all possible (usually integer) displacements with respect to $\vec{X}$ within the search area $SA(\vec{X})$ in the previous image:

$$CS^{\max} = \left\{ \vec{C} \mid -N \leq C_X \leq N, -M \leq C_y \leq M \right\} \tag{1}$$

where N and M are constants limiting $SA(\vec{X})$. A block $B(\vec{X})$ centred at $\vec{X}$ and of size X by Y, consisting of pixel positions $\vec{x} = \begin{pmatrix} x \\ y \end{pmatrix}$ in the present picture n, is

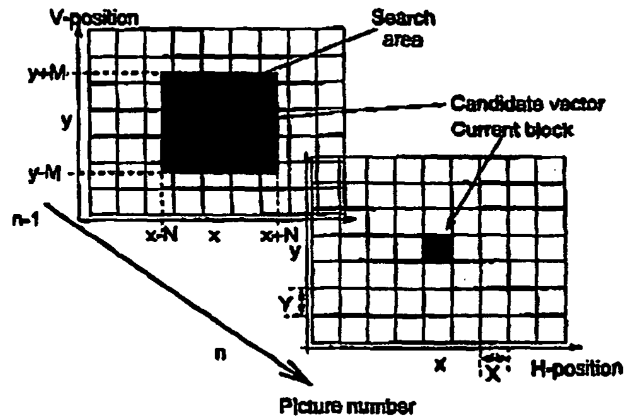


Figure 1: Full-search block-matching.

defined:

$$B(\vec{X}) = \{\vec{x} \mid X_x - X/2 \leq x \leq X_x + X/2 \wedge X_y - Y/2 \leq y \leq X_y + Y/2\} \tag{2}$$

The displacement vector $\vec{D}(\vec{X}, n)$ resulting from the block-matching process, is a candidate vector $\vec{C}$ which yields the minimum value of an error function $(\vec{C}, \vec{X}, n)$:

$$\vec{D}(\vec{X}, n) \in \left\{ \vec{C} \in CS^{\max} \mid \epsilon(\vec{C}, \vec{X}, n) \leq \epsilon(\vec{V}, \vec{X}, n) \forall \vec{V} \in CS^{\max} \right\} \tag{3}$$

If, which is the common case, the vector $\vec{D}(\vec{x}, n)$ with the smallest matching error is assigned to all pixel positions x in the block $B(\vec{X})$:

$$\forall \vec{x} \in B(\vec{X}) : \vec{D}(\vec{x}, n) = \vec{D}(\vec{X}, n) \tag{4}$$

rather than to the centre pixel only, a large reduction of the number of computations is achieved.

As an implication, consecutive blocks $B(\vec{X})$ are not overlapping. The error value for a given candidate vector $\vec{C}$ is a function of the luminance values of the pixels in the current block and those of the shifted block from a previous picture, summed over the block $B(\vec{X})$. A common choice, which we too shall use, is the sum of the absolute differences:

$$\epsilon(\vec{C}, \vec{X}, n) = \sum_{\vec{x} \in B(\vec{X})} \left| F(\vec{x} - \alpha\vec{C}, n-1) - F(\vec{x} + (1-\alpha)\vec{C}, n) \right| \tag{5}$$

where α is a constant, $0 \leq \alpha \leq 1$, determining the temporal position between the two pictures, where the vector field has to be valid.

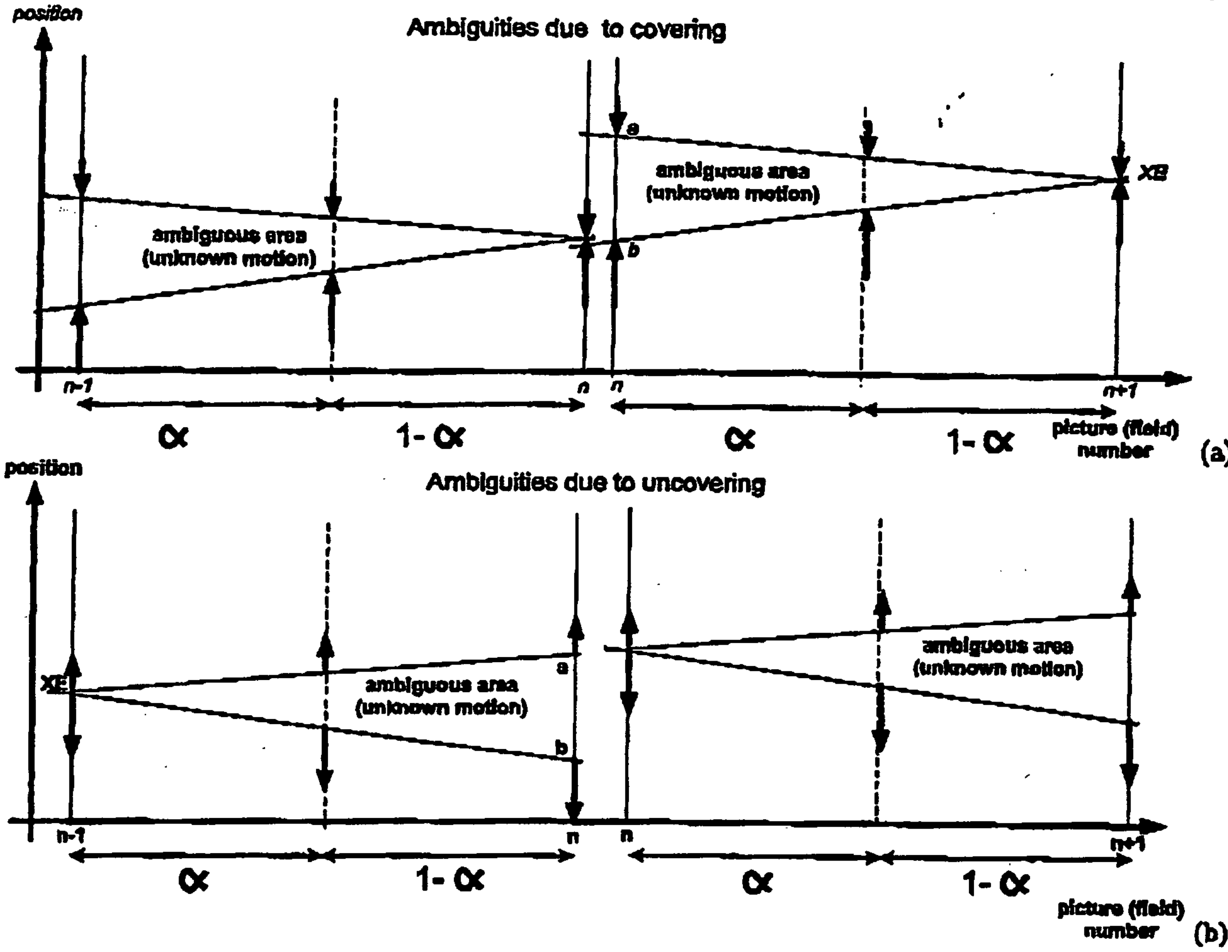


Figure 2: In case of covering, (a), unambiguous motion estimation can result only by calculating the match errors by shifting a previous picture towards the current, as only the previous picture contains all information present in the current. In case of uncovering, (b), unambiguous motion estimation can result only by calculating the match errors by shifting a current picture towards the previous, as only the current picture contains all information present in the previous.

2.2 Modification of the FS block matcher to prevent ambiguities

The improvement proposed, results from the observation that in areas where covering occurs, correct motion vectors can only be estimated with an estimator using $\alpha = 1$. Similarly, for uncovering only correct vectors are found with an estimator using $\alpha = 0$.

Vector estimators calculating vectors for intermediate temporal instances have difficulties with both covering and uncovering, be it that their worst case area of ambiguity is smaller than for the extreme estimators. (The worst case ambiguity is least for the estimator applying $\alpha = 0.5$). The Figures 2a and 2b illustrate the effect of α on the size of the ambiguous area.

The first step in improving the block matcher for covering and uncovering situations, *regardless the required value of α for the interpolated picture*, results by changing equation 5 to:

$$e_c(\vec{C}, \vec{X}, n) = \sum_{\vec{x} \in B(\vec{X})} \left| F(\vec{x} - \vec{C}, n-1) - F(\vec{x}, n) \right| \qquad (6)$$

in case an area of covering, as indicated by the covering/uncovering detector, e.g. the one described in [6]and to

$$e_c(\vec{C}, \vec{X}, n) = \sum_{\vec{x} \in B(\vec{X})} \left| F(\vec{x}, n-1) - F(\vec{x} + \vec{C}, n) \right| \qquad (7)$$

in the event of uncovering. The covering/uncovering detector may use a previous vector field, or a previ-

ous calculation (iteration) of the current vector field, or use methods based on evaluation of match errors calculated between neighbouring pictures.

As a consequence of the proposed modification, there are no ambiguities for the motion estimator, although we have sacrificed the correct temporal instance where the vector field is valid. This shall be detailed in the following sub-section.

2.3 Calculating the required vector field for upconversion from the unambiguous vector field

In a second step of the algorithm, the *retimer*, the time error is corrected. To this end, the vector field is 'projected' to the desired temporal instance, i.e. projected back in time for covering:

$$D^*(\vec{x}, n-1+\alpha) = D(\vec{x} + (1-\alpha)\vec{D}(\vec{x}, n), n) \quad (8)$$

and forward for uncovering:

$$D^*(\vec{x}, n-1+\alpha) = D(\vec{x} - \alpha\vec{D}(\vec{x}, n-1), n-1) \quad (9)$$

This projection reintroduces ambiguous areas, i.e. areas to which no vector is assigned. The origin of this ambiguity is that with one estimate it is unknown whether the discontinuity has moved along the line 'a', or along the line 'b' in Figure 2, hence it is not trivial that the vector taken from e.g. position $\vec{x}$ above the discontinuity is the background vector which should be put in this position in the upconversion vector field. With help of the previous vector field however, it is possible to judge with which of the two possible vectors the edge moves, and hence which is the background and which the foreground velocity.

The retimer first determines the starting position $\vec{x_A}$ of the ambiguity area in the upconversion vector field at time $n-1+\alpha$ by projecting the foreground velocity from the vector edge at position $\vec{x_E}$ in the unambiguous vector field. A small refinement results if the position $\vec{x_A}$ of the edge in the upconversion vector field is not a result of shifting the estimates from one vector field, but is calculated as the weighted (with α) average of the positions in the current and previous vector field. The retimer then fills the space between $\vec{x_A}$ and $\vec{x_E}$ with either the foreground or background velocity, depending on the side of the foreground region (left or right of $\vec{x_E}$) and the sign of the foreground velocity. For this strategy to work, a robust foreground/background determination strategy is needed. We describe three strategies.

In a first strategy, the *average vector foreground/background determination*, we make use of the fact that any vector $v_{\vec{fetch}} = kv_{\vec{FG}} + (1-k)v_{\vec{BG}}$, where k is smaller than 1 and $v_{\vec{FG}}$ and $v_{\vec{BG}}$ are the velocities of the foreground and background objects at position $\vec{x}$, fetches a background velocity from the previous vector field in the case of covering and a foreground velocity in the case of uncovering. The safest vector to use is the average vector $v_{\vec{av}} = 0.5v_{\vec{FG}} + 0.5v_{\vec{BG}}$. More formally, we calculate the two possible positions $\vec{x}_a$ and $\vec{x}_b$ of the edge in the previous image pair, e.g. for covering and a vertical edge at position $\vec{x_E}$ in vector field n:

$$\begin{cases} \vec{x}_a = \vec{x_E} + \vec{D}(\vec{x} - \begin{pmatrix}1\\0\end{pmatrix}, n) \\ \vec{x}_b = \vec{x_E} + \vec{D}(\vec{x} + \begin{pmatrix}1\\0\end{pmatrix}, n) \end{cases} \quad (10)$$

and fetch the vector present at an intermediate position in the previous vector field (covering) in the ambiguous area:

$$\vec{D}_a(\vec{x}, n) = \vec{D}(\frac{\vec{x}_a + \vec{x}_b}{2}, n-1) \quad (11)$$

If we need to fill in the foreground vector in the ambiguous area of the interpolation vector field, we choose between $\vec{x}_a$ and $\vec{x}_b$ the one which is most different from $\vec{D}_a(\vec{x}, n)$.

A variant of this first strategy fetches the background vector from the future for uncovering:

$$\vec{D}_a(\vec{x}, n) = \vec{D}(\frac{\vec{x}_a + \vec{x}_b}{2}, n) \quad (12)$$

with:

$$\vec{x}_a = \vec{x}_1 - \vec{D}(\vec{x} - \begin{pmatrix}1\\0\end{pmatrix}, n-1)\vec{x}_b = \vec{x}_1 - \vec{D}(\vec{x} + \begin{pmatrix}1\\0\end{pmatrix}, n-1 \quad (13)$$

A second strategy, the *twosided self speed foreground/background determination*, uses the fact that for uncovering, positions projected to the past with the background velocity have a higher probability of crossing towards the foreground region than when they are projected with $v_{\vec{av}}$. This is interesting when small relative velocities $v_{\vec{FG}} - v_{\vec{BG}}$ or inaccurately estimated vector fields occur. Because we do not know a priori which velocity is the background velocity, we project the two positions on either side of the edge with its own velocity $v_{\vec{self}}$ (see Figure 3). As we can see for the ideal case, the lower velocity changes from the background velocity at n to the foreground velocity at $n-1$. The probability that a block in foreground in n projects to foreground in n-1 is so high that for practical reasons we can consider it to be 1. All the other probable decisions are shown in table 2.3.

Upper block is in reality:	foreground	background
Decision for upper block	FG	FG or BG
Decision for lower block	FG or BG	FG

Table 1: Probable decisions for the velocities of the block just above and just below the velocity discontinuity for the second foreground/background determination strategy in case of uncovering.

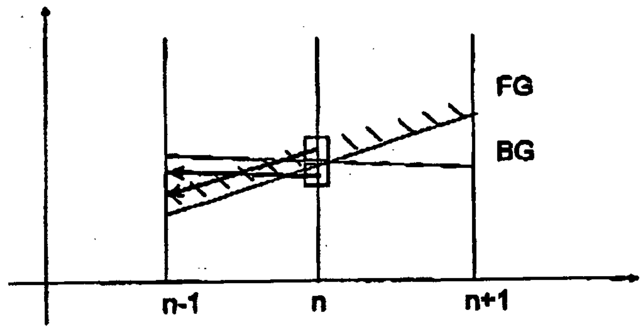


Figure 3: Twosided self speed foreground/background determination.

In case the two projections yield the same (foreground) vector, we have a certain determination. If this vector equals the vector of the upper block, this vector is the foreground velocity vector and vice versa. In case the vectors are different, the method was unsuccesful, and yields an *uncertain* determination. A similar projection towards the future can be applied for the case of covering.

A third strategy, the *edge projection foreground/background determination*, checks for e.g. covering whether the edge between $v_{\vec{FG}}$ and $v_{\vec{BG}}$ in the previous image n is present at position a or b (see Figure 2). If the edge is detected at position a, $v_{\vec{FG}} = \vec{D}(\vec{x} - \begin{pmatrix}1\\0\end{pmatrix}, n+1)$ and vice versa. Care should be taken that the velocities in n are the same velocities as in $n+1$, since other velocity edges can occur in the vicinity of the projection. Obviously again the principle can be applied by substituting uncovering for covering and the future for the past.

The most natural strategy, if one only wants to use vector image from the past, is to use the second foreground/background determination strategy for uncovering and the third one for covering. Alternatively one can use the first strategy for both. It should be noted that the strategies can be enhanced by checking the match errors. In case a crossing to the foreground region occurred, the match errors of the vector in that block should be low. In case we project to a background region that was erronously allotted a foreground vector in the previous image, the errors should be higher.

3 Claims I

Claim 1: A method, and apparatus realizing this method, for detecting motion between previous and next images by optimising a criterion function for candidate vectors the function further depending on data from a previous image shifted over a fraction α times the candidate vector and data from a next image shifted over $\alpha - 1$ times the candidate vector, characterised in that the fraction α may change *within* the picture period.

Claim 2: A method, and apparatus realizing this method, according to claim 1, in which the aforementioned criterion function is a match error, e.g. a sum over a block of pixels of absolute pixel differences, and the optimisation concerns a minimisation of this sum.

Claim 3: A method, and apparatus realizing this method, according to the previous claims, in which the fraction α, is controlled by a covering/uncovering detector.

Claim 4: A method, and apparatus realizing this method, according to any of the previous claims, in which the fraction α is set to 1 in case of covering, and set to 0 in case of uncovering.

Claim 5: A method, and apparatus realizing this method, according to the previous claims, in which the aforementioned covering/uncovering detector decides on data in a previous vector field to adapt the fraction α in the current estimation.

4 Claims II

In the next set of claims we describe how a shifted vector field can be calculated from (the) available vector fields. It is unclear to us whether this can be part of the same patent application, or should be filed seperately.

Claim 1: A method, and apparatus realizing this method, to calculate a vector field, valid at a temporal distance α times the field period from

the previous picture, from neighbouring vector fields by projecting motion vectors, characterized in that the projection direction changes within one output vector field.

Claim 2: A method, and apparatus realizing this method, according to the previous claim, in which the projection direction is controlled by a covering/uncovering detector.

Claim 3: A method, and apparatus realizing this method, according to the previous claim, in which the projection direction points from a next vector field to the required vector field in case of covering and from the previous vector field to the required in case of uncovering.

Claim 4: A method, and apparatus realizing this method, according to the previous claims, in which at the position $\vec{x}_1$ of a discontinuity in the vector field

- a first position $\vec{x}_a$ in the previous (covering) or next (uncovering) vector field is calculated by shifting $\vec{x}_1$ over the first vector at one side of the discontinuity
- a second position $\vec{x}_b$ in the previous (covering) or next (uncovering) vector field is calculated by shifting $\vec{x}_1$ over the second vector at the other side of the discontinuity
- and a third intermediate position, e.g. $(\vec{x}_a + \vec{x}_b)/2$ is calculated
- while finally, the vector fetched with $v_{\vec{av}}$ at the third position in the previous (covering) or next (uncovering) vector field is filled in those regions of the projected vector field in the environment of the disconinuity, to which no vector is projected, in case the background vector $v_{\vec{FG}}$ should be filled in. The vector chosen between $\vec{D}(\vec{x} - \begin{pmatrix}1\\0\end{pmatrix}, n)$ and $\vec{D}(\vec{x} + \begin{pmatrix}1\\0\end{pmatrix}, n)$ which is most different from $v_{\vec{av}}$ is filled in, in case a foreground vector $v_{\vec{FG}}$ should be filled in.

Claim 5: A method, and apparatus realizing this method, according to the previous claims, in which a background velocity is identified as a velocity which crosses the velocity discontinuity and projects to a foreground velocity in the previous picture, whereas a foreground velocity projects to itself .

Claim 6: A method, and apparatus realizing this method, according to the previous claims, in which near discontinuities of the vector field it is tested whether the mentioned discontinuity has moved over the first vector on one side of the edge, or over the second vector on the other side of the edge. In case the edge moves with the first (second) vector, the second (first) vector is filled in those regions of the projected vector field in the environment of the discontinuity, to which no vector is projected, in case a background vector $v_{\vec{BG}}$ should be filled in, and the other vector is filled in, in case a foreground vector $v_{\vec{FG}}$ should be filled in .

Claim 7: A method, and apparatus realizing this method, according to the previous claims, in which the crossing from a background region to a foreground region in the previous image is verified by the match error of the vector in that block.

References

[1] G. de Haan, P.W.A.C Biezen, H. Huijgen, and O.A. Ojo, "Motion compensated picture interpolation apparatus", European Patent Application no: 92201388.3 (PHN14.066), priority date: 15-05-1992.

[2] A.M. Tekalp, "Digital Video Processing", Prentice Hall Signal Processing Series, ISBN 0-13-190075-7, pp. 200-203.

[3] G. de Haan, P.W.A.C Biezen, "Motion compensated interpolation" European Patent Application no: 95200604 (PHN 15.216), priority date: 14-03-1995.

[4] G. de Haan and G.F.M. De Poortere, "Motion compensated frame rate conversion", European Patent Application no: EPA 0 475 499 A1, priority date: 03-09-90.

[5] G. de Haan and A. Pelagotti, 'Motion detection and motion- compensated interpolation', Philips patent application no: PHN16.587, 21-11-97.

[6] G. de Haan and A. Pelagotti, 'Problem area location in an image signal', Philips patent application no. PHN17.065, 20-08-98.

[7] G. de Haan, P.W.A.C. Biezen, H. Huijgen and O.A. Ojo, "True Motion Estimation with 3-D Recursive Search Block-Matching", IEEE Tr. on Circuits and Systems for Video Technology, Vol.3, October 1993, pp. 368-388.

[8] G. de Haan, P.W.A.C Biezen, "Sub-pixel motion estimation with 3-D recursive search block-matching", Signal Processing: Image Communication 6 (1994), pp.229-239.